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1   Method for Assessing the Integrity of a Structure

2

3   The present invention relates to a method for

4   assessing the integrity of a structure. The method

5   according to the present invention involves the

6   measurement of the dimensions of the structure and

7   the loading and thereafter analysing the results of

8   those measurements in order to calculate a value for

9   the integrity of the structure.

10

11 In the process industry, one of the biggest sources

12 of failures and shutdown for process plants is in

13 pressurised piping and vessel systems. In the prior

14 art, systems are known which monitor and assess

15 plants in order to be able to predict a failure.

16 According to the prior art, the wall thickness of

17 structures, such as piping, is simply monitored in

18 order to perform simple calculations and to predict

19 a trend, for instance in the wear and/or the

20 corrosion of such a structure. Alternatively,

21 machinery-based corrosion and vibration monitoring

22 systems are used. These systems are grossly

1   inaccurate as over 85% of failures occur at non-

2   straight pipe areas, due to structural loadings,

3   corrosion/erosion, fatigue, pulsation or vibration

4   ("Hydrocarbon" magazine). The monitoring and

5   assessment technologies according to the prior art

6   are based on "risk analysis". These systems use

7   probability to estimate failure, and in doing so

8   predict suitable inspection intervals. An important

9   disadvantage of such an approach is that these

10   systems do not use real-time measurements in order

11   to calculate real-time load and load changing

12   mechanisms.

13

14   A system for monitoring a pipe segment for instance

15   is known from the European Patent Application EP

16   0358994. The method according to EP 0358994 is

17   adapted to measure a corrosion/erosion trend. The

18   system is confined to the change in the main pipe

19   wall thickness to predict the future thickness of

20   the pipe wall. According to this document the

21   emphasis is on measuring the corrosion/erosion rate

22   and using statistical techniques to predict future

23   rates and trends. The estimated stress in a pipe

24   wall is calculated using the following equation:

25

26   Stress = <u>pressure x radius</u> x estimated factor

27   thickness

28

29   This equation only calculates pressure loading in

30   straight pipes. No other loadings are considered.

31   As the thickness decreases there is a danger of

32   pipewall rupture. Therefore the information is used

1   in order to predict the maximum time interval before
2   the next inpection of the pipe welds. The
3   information collected according to EP0358994, in
4   practice, is not very helpful, as very few plant
5   failures are caused by main pipewall rupture. This
6   means that the information collected by means of
7   EP0358994 has only limited value.
8
9   Additionally, according to the prior art it is known
10   to use acoustic pulsation, vibration and condition
11   monitoring in order to monitor and assess the
12   integrity of a structure. The disadvantage of those
13   techniques is the fact that those techniques are
14   both specialist tasks and extremely expensive.
15   Because of the high costs involved with those
16   techniques normally these techniques are only
17   undertaken if failure is expected or has occurred.
18
19   In view of the disadvantages and limitations of the
20   methods for assessing the integrity of a structure
21   according to the prior art, it is an object of the
22   present invention to provide a method according to
23   the introduction wherein load-changing mechanisms
24   and dimension changing mechanisms, as they occur,
25   are taken into account in the calculations of the
26   integrity of the structure.
27
28   To obtain these objects, the method according to the
29   present invention comprises the steps of:
30
31   i)   collecting data relating to the initial
32   dimensions of the structure,

1   ii)   creating a computer model of the structure,

2   iii) collecting load data relating to the estimated

3   load on the structure,

4   iv)   analysing the structure, using the computer

5   model of the structure and the load data, in

6   order to define areas which are subject to

7   relatively high stresses,

8   v)   measuring, after a time interval, the

9   dimensions of the structure in high stress

10   areas,

11   vi)   updating the computer model of the structure,

12   using the results of step v),

13   vii) re-analysing the structure, using the updated

14   computer model and the load data, in order to

15   calculate a value for the integrity of the

16   structure.

17

18   In the present description the wording "computer

19   model" is used. The wording "computer model" refers

20   to a data set representing a structure, which data

21   set can be analysed by means of an appropriate

22   finite element analysis technology. By means of

23   this finite element analysis technology the strains

24   and stresses occurring in the structure can be

25   calculated.

26

27   In the present description reference is made to "a

28   value for the integrity of the structure". The

29   wording "value for the integrity of a structure"

30   refers to whether a structure is "fit for service"

31   or not. When the value for the integrity of a

32   structure is calculated, it is assessed whether the

1   structure is fit to perform its normal tasks. That

2   means that the value for the integrity of a

3   structure can refer to a minimum wall thickness, a

4   maximum stress in the material of the wall, a

5   maximum strain in the material of a wall, or similar

6   feature.

7

8   According to the present invention data relating to

9   the initial dimensions of a structure are collected.

10   These data are used to create a computer model of

11   the structure. That means that it is possible to

12   use a finite element method in order to calculate

13   strains and stresses in the structure. Thereafter

14   data is collected relating to the estimated load on

15   the structure. By means of the finite element

16   method the structure can then be analysed, using

17   both the computer model and the load data. The

18   result of this analysis is that individual areas can

19   be defined which are subject to relatively high

20   stresses. Because of the fact that the high stress

21   areas are identified, it is clear in which areas of

22   the structure future problems can be expected.

23

24   If the results of the analysis of the structure

25   reveal that the strains and stresses in the

26   structure are within safety limits, the structure

27   thereafter can be used for its normal purpose.

28   After a set time interval the dimensions of the

29   structure will be measured in the high load areas.

30   Because of the fact that high load areas have been

31   defined, the amount of measurements can be limited.

32   That means that the actual measurement of the

6

1   dimensions of the structure in the high load areas

2   involves relatively limited effort.

3   Using the measured dimensions of the structure it is

4   then possible to update the computer model and to

5   re-analyse the structure. This calculation will

6   result in an updated value for the integrity of the

7   structure. This means that the method according to

8   the present invention presents an efficient and

9   effective method for assessing the integrity of a

10   structure.

11

12   According to the present invention the method may

13   further comprise the step of:

14

15   viii) repeating one or more times steps v), vi) and

16   vii).

17

18   According to the present invention it is possible to

19   continuously measure the dimensions of the structure

20   in high load areas. Steps v), vi) and vii) can be

21   repeated after a set time interval, which time

22   interval may be dependent on the calculated value

23   for the integrity of the structure in a former

24   analysis.

25

26   According to the present invention the method may

27   comprise the further step of:

28

29   ix) visualising the results of vii).

30

31   The method according to the present invention is

32   suitable for continuously assessing the integrity of

1   a structure. In order to facilitate the review of

2   the outcome of the assessment, the results of the

3   calculations leading to the value for the integrity

4   of the structure can be presented, for instance, in

5   a table. This table can be presented to a plant

6   manager who thereafter can take necessary actions,

7   if needed.

8

9   According to the present invention the method may

10 comprise the further steps of:

11

12 x)   measuring the actual load on the structure,

13

14 xi) updating the data relating to the load on the

15 structure, and thereafter

16

17 xii) re-analysing the structure, using the computer

18 model and the updated load data, in order to

19 calculate a value for the integrity of the

20 structure.

21

22 The method according to the present invention cannot

23 only be used for assessing the actual dimensions of

24 the structure, the method is also suitable for

25 measuring the actual load on the structure and using

26 the results of those measurements in order to refine

27 the calculations of the value for the integrity for

28 the structure.

29

30 According to the present invention the method may

31 comprise the further step of xiii) repeating one or

32 more times steps x), xi) and xii).

1　Moreover, the method may comprise the further step

2　of:

3

4　xiv) visualising the steps of step xii).

5

6　According to the present invention it is

7　advantageous that the method comprises the steps of

8　installing, after step iv), in high stress areas, a

9　first set of sensors for measuring the dimensions of

10　the structure in said high stress areas.. Moreover,

11　it is advantageous that the method comprises the

12　step of installing, after step iv), in high stress

13　areas, a second set of sensors for measuring the

14　load on the structure in said high stress areas.

15

16　The advantage of these measures is the fact that the

17　data relating to the dimensions of the structure and

18　the actual load on the structure can be collected

19　automatically. In order to process the collected

20　data in real-time it is an advantage that the method

21　comprises the step of connecting the sensors to

22　processing means, such as a computer, for

23　transmitting data from the sensors to the processing

24　means in real-time.

25

26　The method according to the present invention can be

27　used for new systems. The method, however, is also

28　suitable for structures which already have been used

29　during a certain time frame. In those cases it is

30　advantageous that the method comprises the step of

31　prior to step iv), collecting data relating to known

32　defects of the structure and thereafter using said

1   defect-data, the computer model of the structure and
2   the load-data for defining areas which are subject
3   to relatively high loads.
4
5   By adding the data relating to known defects of the
6   structure the calculation of high load areas in the
7   structure can be refined. Deterioration and growth
8   of the defects can then be measured and analysed.
9
10 In case there are no known defects, it is possible
11 that the method comprises the step of prior to step
12 iv), estimating the minimum size of defect in the
13 structure and thereafter using said estimated
14 defect-data, the computer model of the structure and
15 the load-data for defining areas which are subject
16 to relatively high loads. Moreover, it is possible
17 that the minimum size of the defect is estimated to
18 be equal to the precision the measurement equipment,
19 used for measuring the dimensions of the structure.
20
21 When the structure, to be analysed, is used for a
22 certain time period, and the load history on the
23 structure is known, it is possible that the method
24 comprises the step of prior to step iv), collecting
25 data relating to the load-history on the structure
26 and thereafter using said load-history, the computer
27 model of the structure and the load-data for
28 defining areas which are subject to relatively high
29 loads. Using this extra step of collecting data
30 relating.to the load-history means that initial
31 calculations of high-load areas can be refined.
32

1   The invention also relates to a processing

2   arrangement for assessing the integrity of a

3   structure, provided with processing means, such as a

4   computer, for using data relating to the dimensions

5   of the structure and the load on the structure in a

6   calculation of a value representing the integrity of

7   the structure, wherein the processing arrangement is

8   provided with sensors to measure data relating to

9   the dimensions of the structure and the load on the

10   structure, the sensors being adapted to transmit

11   said data in real-time, wherein the processing means

12   are provided with receiving means for receiving said

13   data and wherein the processing means are adapted to

14   analyse the data in order to update the calculation

15   of the value representing the integrity of the

16   structure.

17

18   Preferably the processing arrangement is provided

19   with representation means for visualising the

20   results of the calculation of the value for the

21   integrity of the structure.

22

23   According to the invention it is possible that the

24   sensors used in the processing arrangement are

25   adapted to measure pressure exerted on the

26   structure, environmental loads, temperature,

27   mechanical loading on the structure, fluid loading

28   on the structure, vibration or acceleration

29   experienced by the structure.

30

1   The invention also relates to a structure, such as a

2   plant, provided with a processing arrangement as

3   described above.

4

5   The method according to the present invention can be

6   entirely controlled by a suitable computer program

7   after being loaded by the processing arrangement.

8   Therefore, the invention also relates to a computer

9   program product comprising data and instructions

10   that after being loaded by a processing arrangement

11   provides said arrangement with the capacity to carry

12   out a method as defined above.

13

14   Also a data carrier provided with such a computer

15   program is claimed.

16

17   Below, the invention will be explained in detail

18   with reference being made to the drawings. The

19   drawings are only intended to illustrate the

20   invention and not to limit its scope which is only

21   defined by the dependent claims.

22

23   Fig 1 shows a schematic overview of a processing

24   arrangement for assessing the integrity of a vessel.

25   Fig 2 shows a visual representation of the

26   calculations of a value for the integrity of a

27   structure.

28

29   Fig 3 shows a schematic overview of the software

30   used according to the present invention.

31

1   Fig 4 shows a diagram indicating the relation

2   between inspection costs, the number of inspections

3   and the corresponding risk.

4

5   In Fig 1 a schematic overview is shown of a

6   processing arrangement 10 for assessing the

7   integrity of a vessel. In order to assess the

8   integrity of the vessel 20, at an initial stage a

9   computer model will be created representing the

10   dimensions of the vessel 20. When creating said

11   computer model the presence of corroded areas 21 and

12   the presence of flaws, pits and cracks 22 can be

13   taken into account. The processing arrangement 10

14   comprises sensors 11 which are installed in high

15   load areas of the vessel 20. In Fig 1 only one

16   sensor is shown. In practice, several sensors will

17   be installed in order to allow a good overview of

18   the condition, strains and stresses in the vessel

19   20. The sensor 11 by means of a line 12 is

20   connected to a data logger 13. The data logger 13

21   is connected to processing means 14, such as a

22   computer. The computer 14 is provided with suitable

23   software in order to process the data generated by

24   the data logger 13. A possible architecture for the

25   software to be used in the computer 14 is described

26   with reference to Fig 3. By means of the sensor 11

27   the actual dimensions of the vessel 20 and the load

28   exerted on the vessel can be continuously measured

29   and can be forwarded to the computer 14. The

30   updated information sent to the computer 14 can be

31   used to constantly reanalysis the structure and

1   recalculate values for the integrity of the

2   structure.

3

4   The results of the calculations can be visualised,

5   for instance by means of a document centre 15. The

6   document centre 15 can be used, for instance, for

7   printing tables and overviews (see Fig 2), in order

8   to inform the responsible plant manager.

9

10   In Fig 1 reference numbers 23 and 24 are used for a

11   graphic representation of flaws, pits and cracks

12   which can be present in the vessel wall. During the

13   lifetime of the vessel the actual size of such

14   flaws, pits and cracks(in 3-d) will be used in

15   calculations of the value for the integrity of the

16   structure. That means that according to the present

17   invention no estimations of trends are used. The

18   actual sizes of the flaws, pits and cracks in the

19   system will be used when calculating the

20   representative value for the integrity of the

21   structure.

22

23   According to the present invention it is possible to

24   add a warning system. This warning system could

25   produce a warning when the value for the integrity

26   of the structure drops below a specific

27   predetermined level. It is also possible to

28   indicate on a visual representation the value for

29   the integrity of the structure has dropped below a

30   certain mimimum.

31

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1   In Fig 2 a possible outcome of the calculations are

2   shown. According to the requirements of a user, the

3   outcome of the calculations provides information on,

4   but not limited to, the working pressure inside the

5   vessel, the number of fatigue cycles to date, the

6   number of fatigue cycles remaining, current

7   corrosion rate, date until inspection is required,

8   the current safety factor, current risk factors,

9   etc. The visual representation of the outcome of

10   the calculations of the value for the integrity of

11   the structure can be tailored upon a user's request.

12   The visual representation according to Fig 2

13   provides a plant manager with a user-friendly

14   overview of the integrity of a structure.

15

16   In Fig 3 a schematic overview is given of a software

17   program which can be used in the method and

18   processing arrangement according to the present

19   invention. Because of the fact that the software

20   module provides an analysis system for plant real-

21   time integrity assessment, the software module could

22   be referred to as "Aspria". The software system is

23   built up from several modules. The overall system

24   will be referred to as "Integri-TECH".

25

26   The layout of the software system is shown in Fig 3.

27   The central part of the system is a so-called

28   management system or core system. The core system

29   manages and controls the components and will produce

30   the visual representation as shown in Fig 2. The

31   core system enables the different modules to work

1   together in order to produce a single outcome,

2   representing the integrity of a structure.

3

4   The core system comprises an analysis tool (Smart

5   FEA), which is a program based on finite element

6   analysis technology. This module includes advanced

7   error estimation techniques. The module contains

8   the "as-built" model of the structure to be

9   analysed, plus components and receives the regular

10   measurement data. When receiving the measurement

11   data this module will update the finite element

12   model and will perform an advanced finite element

13   analysis and thereafter passes the results to

14   further modules.

15

16   The core system also comprises a module for

17   assessment of a corrosion patch. This module can be

18   referred to as "envelope corrosion patch assessment"

19   (ECPA), which has been derived to assess the effects

20   of patches of corrosion in the various regions of

21   each structure to be analysed. The module generates

22   an envelope of possible conditions that will allow

23   the system to predict the earliest possible danger

24   signs for each structure. The corrosion patches can

25   be located and automatically updated every time a

26   corrosion measurement is taken or can be

27   automatically generated from measurement data,

28   adaptively meshed and can be dynamically positioned

29   anywhere on the structure to be analysed for

30   detailed finite element analysis. The results of

31   the analysis are modified to account for the most

32   likely severe and emerging patch shape and where the

1   results are becoming nearer to limiting values,

2   recommendations are passed back through the system

3   in order that the finite element analysis can modify

4   the finite element mesh in order to re-analysis the

5   system whereby the corrosion patches are included.

6

7   The core system further comprises a corrosion

8   trending analysis (CTA). This modules analyses the

9   history and trends and the future effects of

10   corrosion and erosion in the system. This module

11   moreover builds up on a history of the effects and

12   derives continually updating correlations to predict

13   corrosion rates, patterns, etc in order to be used

14   in a further statistical analysis module.

15

16   In case the structure to be analysed is in a high

17   temperature area, for instance in high energy piping

18   systems, a creep assessment system (CAS) can be

19   used. This module will analyse the temperature and

20   time history of a certain structure. Thereafter a

21   creep analysis of the system will be carried out to

22   simulate the stress changes due to time dependent

23   temperature effects in the piping system and will

24   build up a history of the effects and derive

25   continually updating correlations to predict creep

26   rates, patterns etc for the statistical analysis

27   module.

28

29   In case the structure to be analysed is subject to

30   acoustic pulsation, such as in gas compression

31   systems, a further harmonic-acoustic simulator (HIS)

32   can be used. This modules analyses the acoustic

1   pulsations in the system by harmonic analysis to

2   simulate the stress changes due to acoustic

3   pulsations in the piping system. The history is

4   then stored and trends are predicted for the future

5   effects of acoustic pulsations in the system and the

6   system builds up a history of the effects and

7   derives continually updating correlations to predict

8   cyclic stress patterns. These cyclic stress patterns

9   can be used in a statistical analysis module.

10

11   In case the structure to be analysed is subject to

12   transient fluid flow conditions, such as in pumping

13   systems, the core system moreover uses a transient

14   simulator (TS). This module analyses the transient

15   fluid flow effects in the system by time history

16   analysis to simulate the stress changes due to

17   transient fluid flow effects in the piping system.

18   The history is then stored and trends predicted for

19   the future effects of transient fluid flow effects

20   in the system and the system builds up a history of

21   the effects and derives continually updating

22   correlations to predict cyclic stress patterns.

23   These cyclic stress patterns can be used in a

24   statistical analysis module.

25

26   The core system moreover comprises a statistical

27   analysis module. This module takes all of the

28   piping system loading history, cyclic patterns,

29   operational data, corrosion and erosion and B-Tech

30   vibration data and trends. These data then are

31   statistically analysed to provide realistic and

32   meaningful loading for first time history data for

1   the defect and fracture module. The same

2   information can be used in a fatigue life prediction

3   module to predict the remaining lifetime of the

4   structure before shutdown or failure. Standard

5   statistical analysis is then employed in the system.

6

7   The core system moreover is provided with a module,

8   adapted to receive "live measurements", including

9   frequency data, measured live by accelerometers, at

10   small bore branch connections. This module is

11   referred to as "B-Tech. The B-Tech part of the

12   system then performs..extensive mathematical

13   correlations, algorithms and techniques to predict

14   the effect of the vibration and more importantly to

15   predict the fatigue life for the analysed structure

16   automatically from the measured data. The module,

17   if needed, can alert the user and can prevent

18   failure. Another important part of this module is

19   that the module isn't only capable of predicting the

20   fatigue life from vibration, but will also predict

21   which vibration excitation will cause problems for

22   each particular arrangement and will indicate these

23   vibration excitation if that level of vibration is

24   detected.

25

26   Results of these calculations will then be passed to

27   a further defect and fracture and FLP modules.

28

29   The core system moreover is provided with a liquid

30   sloshing simulator. This module performs the

31   simulation and assessment of liquid sloshing that

32   can take place when a vessel is located on a moving

1   object, such as a ship. Such liquid sloshing is
2   very detrimental to the integrity of the vessel and
3   can be catastrophic. Therefore it is most important
4   to assess the exact effects of the sloshing on the
5   integrity of the vessel. The liquid sloshing
6   simulator is adapted to simulate sloshing and to
7   predict the interaction of the sloshing with the
8   pressure vessel or a ship wall. The response of
9   these loadings to the ship (or a vehicle) motion is
10   measured and the cyclic loading pattern is generated
11   and passed through the finite element analysis
12   system for dynamic stress analysis. This analysis
13   is followed by a defect and fatigue analysis in
14   order to verify the integrity of the structure.
15

16   The core system moreover comprises a defect and
17   fracture module. This module performs the fracture
18   mechanics assessment. The system is adapted to
19   monitor, analyse and assess the growth of any defect
20   in the structure. The system integrity is then
21   quantified in respect of limiting crack and flaw
22   sizes that will affect the integrity. The location,
23   size and type of any possible defect or arrangement
24   of cumulative defects can be assessed and also
25   postulated defect assessments can be carried out.
26   For instance, every well in a structure, is assessed
27   and every range of defects is assessed at every
28   weld.
29

30   A further module present in the core system is the
31   fatigue life prediction module (FLP). This system
32   performs the fatigue life predictions.

20

1   The core system manages the various modules which
2   are shown in Fig 3. The specific features of those
3   six modules will be described below.
4
5   Aspria (analysis system for plant real time
6   integrity assessment) is an analysis, monitoring and
7   assessment system that can be connected to any
8   pressurised plant or structural system than can
9   deteriorate by erosion, corrosion or general
10 time/operation exposure and/or vibration. This
11 module quantifies the system's integrity, assesses
12 the.effects of all loadings, stresses, defects and
13 predicts inspection and repair intervals as well as
14 plant life and safety. This is all done "on-line",
15 "live" or as "continuous monitoring system".
16
17 The Aspria module constantly measures geometric
18 thickness values in piping systems effected by
19 corrosion, erosion, vibration, etc. A detailed
20 geometric update is performed and the unit, whether
21 a piece of plant, such as pipework, a structure or
22 similar, will undergo an automatic and complete
23 finite element stress analysis using for instance
24 Smart-FEA (see above) and advanced error estimation
25 techniques to determine the degree of accuracy.
26 Defects, cracks or corrosion patches will be
27 thoroughly analysed automatically and a system
28 fatigue life automatically calculated. This will
29 lead to prescribed inspection and repair intervals,
30 and a quantified plant life. All loadings,
31 including process, mechanical and environmental
32 loadings, will be included in the assessment. If

1   the structure is used on a ship, the loading will

2   include sea motion.

3

4   The second module which can be used in the software

5   is Vecor (vessel corrosion analysis system for plant

6   real time integrity assessment). Vecor is an

7   analysis, monitoring and assessment system that can

8   be connected to any pressure vessel, tank or storage

9   system which can deteriorate by erosion, corrosion

10   or general time/operation exposure and/or vibration.

11   The system includes FPSO and ship movements and the

12   liquid sloshing and fluid structural interaction

13   effect of vessels on ships. Moreover Vecor will

14   include acceleration effects. It quantifies the

15   system and integrity, assesses the effects of all

16   loadings, stresses defects etc and predicts

17   inspection and repair intervals as well as plant

18   life and safety. This is all done "on-line", "live"

19   or as a continuous monitoring system. The Vecor

20   system will constantly measure geometric thickness

21   values in pressure vessels, exchangers and tanks

22   affected by corrosion, erosion, vibration etc.

23   Another item that Vecor can measure is the motion of

24   a ship or a platform. A detailed geometric and

25   loading update will then be performed and the

26   structure will undergo an automatic and complete

27   finite element stress analysis using for instance

28   Smart-FEA (see above) and advanced error measurement

29   techniques in order to determine the degree of

30   accuracy. Liquid sloshing effect within the vessel

31   will be simulated and assessed if appropriate (that

32   means when a ship pitches, heaves and rolls).

1   Interaction effects of the liquid sloshing and the

2   vessel structure response will also be assessed.

3   Defects, cracks or corrosion patches will be

4   thoroughly analysed automatically and a system

5   fatigue life automatically produced. This will lead

6   to prescribed inspection and repair intervals, plus

7   quantified plant life. All loadings, including

8   process, mechanical and environmental loadings will

9   be included in the assessments, including (if

10   appropriate) sea motion.

11   A further module to be used in the system is HEP-

12   TECH (high energy piping technology). HEP-TECH is

13   an analysis monitoring and assessment system which

14   can be connected to high energy or high temperature

15   piping systems in power stations or other markets,

16   where deterioration by creep, support load

17   variation, load and stress redistribution, high

18   temperature effects or general time/operation

19   exposure and/or vibration occurs. It quantifies the

20   system integrity, assesses the effects of all

21   support behaviour, loadings, stresses, defects and

22   predicts inspection and repair intervals as well as

23   plant life and safety. This is all done "on-line",

24   "live" or as "continuous monitoring system. The

25   HEP-TECH will constantly measure support load values

26   effected by deterioration and load redistribution

27   due to high temperatures of creep. A detailed load

28   update will then be performed and the pipework will

29   then undergo an automatic and complete finite

30   element stress analysis and advanced error

31   estimation techniques to determine the degree of

32   accuracy. The system will be assessed and the load

1   corrections required highlighted for adjustments,

2   which should be made to ensure piping and structural

3   integrity. Defects, cracks or potential areas for

4   such will be thoroughly analysed automatically and

5   the system fatigue life will be produced

6   automatically. This will lead to a prescribed

7   inspection and repair intervals, plus quantified

8   plant life. The assessments will include all

9   loadings such as process, mechanical and

10   environmental loadings. The potential for "leak

11   before break" will also be assessed.

12

13   A further module is the AP-Tech (acoustic pulsation

14   technology). AP-Tech is an analysis, monitoring and

15   assessment system to monitor, predict, similate and

16   assess the effects and levels of acoustic energy

17   waves and frequencies in process plant piping

18   systems. It also assesses the levels of dynamic

19   excitation and vibration of the piping system but

20   also has a module to prevent and identify a solution

21   to the majority of small bore bench connection

22   stress, vibration and fatigue problems. AP-Tech

23   quantifies the piping system integrity, assesses the

24   effects of all pulsation and piping behaviour,

25   dynamic and fluid loadings, stresses, defects and

26   small bore branches and predicts inspection and

27   repair intervals as well as plant life and safety.

28   These are all done "on-line", "live" or as a

29   "continous monitoring system". The AP-Tech system

30   would constantly measure life acoustic pulsation

31   pressure waves and the associated frequency and

32   vibration values effected by acoustic pulsation and

1   vibration, etc. The detailed dynamic loading update

2   will then be performed and the pipework will undergo

3   an automatic and complete dynamic finite element

4   stress analysis. Moreover, error estimation

5   techniques will be used in order to determine the

6   degree of accuracy. AP-Tech will use either a

7   pressure transducer or a non-intrusive method to

8   measure acoustic pulsations. The system will be

9   dynamically assessed, the acoustic pulsation

10   similated and the acoustic-dynamic-vibration load

11   cycle pattern and subsequent fatigue life will be

12   determined.. A computational fluid dynamic similator

13   will optionally be attached to allow a user to

14   "visualise" the acoustic pulsation behaviour of the

15   system. All necessary timescales and indications of

16   work areas required will be produced "automatically

17   which should be made to ensure piping and structural

18   integrity. Defects, cracks or potential for such

19   will be thoroughly analysed automatically and the

20   system fatigue life will be produced automatically,

21   which will lead to prescribed inspection and repair

22   intervals, plus a quantified plant life. All

23   loadings, including process, mechanical, pulsation,

24   acoustic, vibration and environmental loadings will

25   be included in the assessment.

26

27   A further module to be used in the system is F-Tech.

28   This is a module which provides beneficial analysis

29   and monitoring and assessment for the majority of

30   piping and vessel-tank flange connections. The

31   problems to monitor involve stress, vibration,

32   leakage and fatigue. F-Tech quantifies the flange

1   joint integrity, assesses the effects of all flange

2   loadings, gaskets, bolts, stresses and predicts

3   inspection and repair intervals as well as plant

4   life and safety. This is all done "on-line", "live"

5   or as "continuous monitoring" system. F-Tech will

6   provide a detailed geometric update of the monitored

7   area and then the area will undergo an automatic and

8   complete finite element stress analysis and advanced

9   error estimation techniques to determine the degree

10   of accuracy. Flange displacement and rotation will

11   be assessed along with gasket seating pressure in a

12   live and automatic mode. This will be thoroughly

13   analysed "automatically" and the system fatigue

14   life, joint relaxation plus potential for joint

15   leverage will be automatically produced. This will

16   lead to prescribed inspection and repair intervals,

17   plus quantified plant life. All loadings including

18   process, mechanical and environmental loadings will

19   be included in the assessment.

20

21   A further module to be used is called Trans-Tech.

22   This module is adapted to monitor, predict, similate

23   and assess the effects of the majority of piping

24   transient events such as fluid transient and energy

25   waves and frequencies in process plants piping

26   systems. It also assesses the levels of dynamic

27   excitation and vibration of the piping system.

28   Moreover, Trans-Tech has a module to prevent and

29   identify a solution to the majority of small bore

30   branch connections stress, vibration and fatigue

31   problems. Trans-Tech quantifies the piping system

32   integrity, assesses the effects of all fluid

1   transient and piping behaviour, dynamic and fluid

2   loadings, stresses, defects, small bore branches and

3   thereafter predicts inspection and repair intervals

4   as well as plant life and safety. This is all done

5   "on-line", "live" or as a "continuous monitoring"

6   system. A computation fluid dynamic simulator will

7   optionally be attached to allow clients to visualise

8   the acoustic pulsation behaviour of the system. All

9   necessary timescales and indications of work areas

10   required will be produced automatically which should

11   be made to ensure piping and structural integrity.

12

13   All six modules, described above, have the option of

14   utilising accelerometers to include the effects of

15   system vibration. All systems have preset intervals

16   for the automatic measurement readings and

17   subsequent re-analysis. This is determined by the

18   user and could be adapted in order to analyse and

19   measure every hour all day, or any other time

20   interval. The cost of the modular architectural

21   software the Integri-Tech system can be set up for

22   any structure, any piece of plant, pressure vessels,

23   equipment, civil buildings, structures, ships and

24   buried pipes.

25

26   In order to collect the data to be processed by the

27   software as described above the processing

28   arrangement according to the present invention uses

29   measurement hardware components which will include:

30

31   Ultrasonic thickness, ultrasonic blanket thickness

32   measuring devices, accelerometers, data transmittal

1   devices, data interface devices, acoustic

2   measurement systems, pressure transducers, non-

3   intrusive PVDF systems, pipe support load

4   measurement cells, strain gauges, ground settlement

5   gauges, gyroscopes and ship-vehicle motion devices,

6   acoustic emission systems, patch corrosion

7   measurement devices, radiography interfaces, MAP

8   scan interfaces, intelligent pigging interfaces, and

9   crack growth measurement devices.

10

11   The advantages of using the system according to the

12   present invention include:

13

14   The generation of information to protect inspection

15   and remedial action plans. Since all necessary

16   information on the critical areas of a structure are

17   known, the use of the system will lead to a

18   reduction of risks and a reduction of inspection

19   costs. Moreover, the system provides real time

20   information on the integrity of the system, which

21   enables prompt action if required.

22

23   In Fig 4 the possible advantages of the system

24   according to the present invention are shown. Line

25   X represents the amount of costs involved with a

26   respective number of inspections. Line Y represents

27   the relation between possible risks and the number

28   of inspections. Line Z represents a modified

29   relation between risks involved and the number of

30   inspections when using the system according to the

31   present invention.

32

1   Fig 4 shows that using the system according to the
2   present invention will lead to a lower level of
3   risk, while at the same time the number of
4   inspections (meaning the costs involved as
5   inspections) will decrease.

1   CLAIMS

2

3   1. Method for assessing the integrity of a
4   structure, comprising the steps of:

5

6   i)   collecting data relating to the initial
7   dimensions of the structure,
8   ii)   creating a computer model of the structure,
9   iii) collecting data relating to the estimated load
10   on the structure,
11 iv)   analysing the structure, using the computer
12   model of the structure and the load data, in
13   order to define areas which are subject to
14   relatively high stresses,
15 v)   measuring, after a time interval, the
16   dimensions of the structure in high stress
17   areas,
18 vi)   updating the computer model of the structure,
19   using the results of step v),
20 vii) re-analysing the structure, using the updated
21   computer model and the load data, in order to
22   calculate a value for the integrity of the
23   structure.

24

25 2. Method according to Claim 1, wherein the method
26 comprises the step of:
27 viii) repeating one or more times steps v), vi) and
28 vii).

29

30 3. Method according to Claim 1 or 2, wherein the
31 method comprises the step of:
32 ix)   visualising the results of step vii).

1   4. Method according to Claim 1, 2 or 3, wherein the

2   method comprises the steps of:

3   x)   measuring the actual load on the structure,

4   xi)   updating the data relating to the load on the

5   structure, and thereafter

6   xii) re-analysing the structure, using the computer

7   model and the updated load data, in order to

8   calculate a value for the integrity of the

9   structure.

10

11   5. Method according to Claim 4, wherein the method

12   comprises the step of:

13   xiii) repeating one or more times steps x), xi) and

14   xii).

15

16   6. Method according to Claims 4 or 5, wherein the

17   method comprises the step of:

18   xiv) visualising the results of step xii).

19

20   7. Method according to one of the preceding claims,

21   wherein the method comprises the step of installing,

22   after step iv), in high stress areas, a first set of

23   sensors for measuring the dimensions of the

24   structure in said high stress areas.

25

26   8. Method according to one of the preceding claims,

27   wherein the method comprises the step of installing,

28   after step iv), in high stress areas, a second set

29   of sensors for measuring the load on the structure

30   in said high stress areas.

31

1   9. Method according to Claim 7 or 8, wherein the
2   method comprises the step of connecting the sensors
3   to a processing means, such as a computer, for
4   transmitting data from the sensors to the processing
5   means in real time.
6

7   10. Method according to one of the preceding claims,
8   wherein the method comprises the step of prior to
9   step iv), collecting data relating to known defects
10   of the structure and thereafter using said defect-
11   data, the computer model of the structure and the
12   load-data for. defining areas which are subject to
13   relatively high loads.
14

15   11. Method according to one of the preceding claims,
16   wherein the method comprises the step of prior to
17   step iv), estimating the minimum size of defects in
18   the structure and thereafter using said estimated
19   defect-data, the computer model of the structure and
20   the load-data for defining areas which are subject
21   to relatively high loads.
22

23   12. Method according to Claim 11, wherein the
24   minimum size of the defects is estimated to be equal
25   to the precision of the measurement equipment, used
26   for measuring the dimensions of the structure.
27

28   13. Method according to one of the preceding claims,
29   wherein the method comprises the step of prior to
30   step iv), collecting data relating to the load-
31   history on the structure and thereafter using, said
32   load-history, the computer model of the structure

1 and the load-data for defining areas which are

2 subject to relatively high loads.

3

4 14. Processing arrangement for assessing the

5 integrity of a structure, provided with processing

6 means, such as a computer, for using data relating

7 to the dimensions of the structure and the load on

8 the structure in a calculation of a value

9 representing the integrity of the structure, wherein

10 the processing arrangement is provided with sensors

11 to measure data relating to the dimensions of the

12 structure and the load on the structure, the sensors

13 being adapted to transmit said data in real-time,

14 wherein the processing means are provided with

15 receiving means for receiving said data and wherein

16 the processing means are adapted to analyse the data

17 in order to update the calculation of the value

18 representing the integrity of the structure.

19

20 15. Processing arrangement according to Claim 14,

21 wherein the processing arrangement is provided with

22 representation means for visualising the result of

23 the calculation of the value representing the

24 integrity of the structure.

25

26 16. Processing arrangement according to Claim 14 or

27 15, wherein the sensors are adapted to measure

28 pressure exerted on the structure.

29

30 17. Processing arrangement according to Claim 14 or

31 15, wherein the sensors are adapted to measure

32 temperature.

1 18. Processing arrangement according to Claim 14 or
2 15, wherein the sensors are adapted to measure
3 mechanical loading on the structure.
4
5 19. Processing arrangement according to Claim 14 or
6 15, wherein the sensors are adapted to measure fluid
7 loading on the structure.
8
9 20. Processing arrangement according to Claim 14 or
10 15, wherein the sensors are adapted to measure
11 vibration.
12
13 21. Processing arrangement according to Claim 14 or
14 15, wherein the sensors are adapted to measure
15 acceleration experienced by the structure.
16
17 22. Structure, such as a plant, provided with a
18 processing arrangement according to Claims 14-21.
19
20 23. A computer program product comprising data and
21 instructions that after being loaded by a processing
22 arrangement provides said arrangement with the
23 capacity to carry out a method according to Claims
24 1-13.
25
26 24. A data carrier provided with a computer program
27 product according to Claim 23.